LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA7 | Colne Valley

Flood risk assessment (WR-003-007)

Water resources

November 2013

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Department for Transport

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise three parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 Specific appendices for each community forum area (CFA) are also provided. For the Colne Valley area (CFA7) these are:

- a water resources assessment (Volume 5: Appendix WR-002-007); and
- a flood risk assessment (i.e. this appendix).

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5, Water Resources and Flood Risk Assessment Map Book.

1.2 Scope of this assessment

1.2.1 This flood risk assessment (FRA) considers the assessment of flood risk in CFA7. The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[1] which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

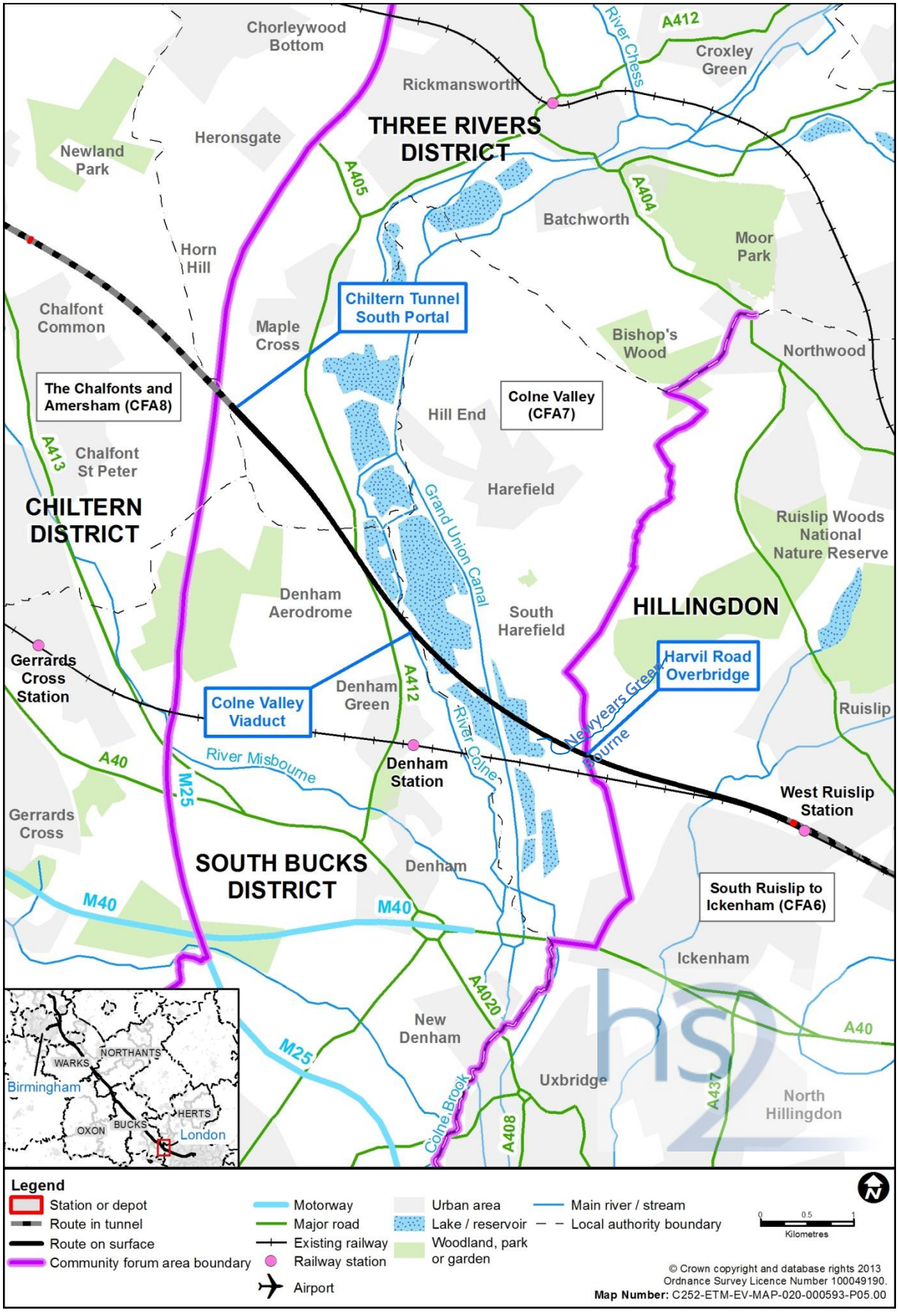
1.2.2 The FRA methodology and a review of the relevant local planning policy documents are provided in Section 2 of this report. The design criteria are provided in Section 3, and Section 4 documents the sources of information that have been reviewed. Section 5 provides a description of the planned works within CFA7. Section 6 considers baseline flood risk, and the risk of flooding to the Proposed Scheme from all relevant sources. Flood risk mitigation measures included within the Proposed Scheme are detailed in Section 7. The effect of the Proposed Scheme on the risk of flooding is considered in Section 8.

1.3 Location

1.3.1 CFA7 covers an approximately 5.7km section of the Proposed Scheme in the London Borough of Hillingdon (LBHi) and the South Bucks, Chilterns and Three Rivers district councils within the counties of Buckinghamshire and Hertfordshire. It extends from Harvil Road in the south-east to the M25 in the north-west as shown in Figure 1. The South Ruislip to Ickenham area (CFA6) and The Chalfonts and Amersham area (CFA8) lie to the south-east and north-west respectively.

[1] Department for Communities and Local Government (2012), *National Planning Policy Framework.*

Figure 1: Colne Valley area



1.3.3 The study area extends to a distance of 1km from the centre line of the Proposed Scheme and includes the parishes of Denham (South Bucks), Chalfont St. Peter (Chilterns) and Chorleywood (Three Rivers). The corresponding council wards are Denham North, Central and Maple Cross, and Mill End.

1.3.4 The route will cross a number of water features within the study area, as identified using the surface water crossing (SWC) references on Map WR-01-008 (Volume 5, Water Resources and Flood Risk Assessment Map Book), including:

- the Newyears Green Bourne (SWC-CFA7-02);
- the Grand Union Canal (GUC) (SWC-CFA7-01); and
- the River Colne (SWC-CFA7-03).

2 Flood risk assessment methodology

2.1 Source-pathway-receptor model

2.1.1 Flood risk is assessed using the source-pathway-receptor model. In this model individual sources of flooding within the study area are identified. The primary source of flooding is rainfall which is a direct source in the short-term (surface water flooding) and can lead to flooding from watercourses (river flooding) and overloaded man-made collection systems (sewer flooding) in the short term or medium term. Stored rainfall, either naturally in below ground aquifers and natural lakes or artificially in impounded reservoirs and canals can lead to flooding when the storage capacity of the system is exceeded. A final source of flooding arises from tidal effects and storm surges caused by low pressure systems over the sea.

2.1.2 For there to be a risk of flooding at an individual receptor there must be a pathway linking it to the source of flooding. The pathways within the study area are assessed by reviewing national datasets that show the spatial distribution of flood risk. The associated risk magnitude is then categorised.

2.1.3 Receptors considered in this assessment include the Proposed Scheme and existing development within 1km of the Proposed Scheme. The Proposed Scheme includes all associated permanent infrastructure. Areas of interest are identified through comparison of the national spatial datasets with the design drawings. Where a risk is identified mitigation is proposed in line with recommendations in the NPPF.

2.1.4 Existing receptors within the study area are identified using Ordnance Survey (OS) mapping information. A high-level screening assessment is then undertaken to identify receptors that are within or in close proximity to an area of flood risk via pathways indicated using the flood risk data sources listed below. The vulnerability of each receptor is classified using Table 2 of the NPPF Technical Guidance Document[2].

2.1.5 The assessment then considers the vulnerability of the receptor with reference to the flood risk category of the source using Table 3 of the NPPF Technical Guidance Document and assesses whether the Proposed Scheme has any potential to influence or alter the risk of flooding to each receptor. Where such potential has been identified, mitigation is proposed based on further analysis.

2.2 Flood risk categories

2.2.1 The level of flood risk is categorised by assessing the design elements against the datasets for each source. A matrix showing the flood risk category associated with each flooding source is presented in Table 1.

[2] Department for Communities and Local Government (2012), *National Planning Policy Framework Technical Guidance.*

Table 1: Flood risk category matrix for all flooding sources

Source of flooding	Flood risk category				
	No risk	**Low**	**Medium**	**High**	**Very high**
Rivers		Flood Zone 1	Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Surface water	No surface water flooding.	Surface water flooding <0.3m for 1 in 200 years event.	Surface water flooding >0.3m for 1 in 200 years event; and Surface water flooding <0.3m for 1 in 30 years event.	Surface water flooding >0.3m for 1 in 30 years event.	
Groundwater		Very low-low	Moderate	High-very high	
Drainage and sewer systems	No sewer in vicinity of site.	Surcharge point >20m from site and no pathways.	Surcharge point within 20m of site and restricted pathways.	Sewer network crosses site and pathways exist.	
Artificial sources	Outside of inundation mapping/no pathway exists.	Within inundation mapping/ pathway exists.			

2.3 Regional and local flooding planning policy documents

2.3.1 The lead local flood authorities (LLFA) for the study area are LBHi, Buckinghamshire County Council (BuCC) and Hertfordshire County Council (HCC). The recommendations from the LBHi[3], BuCC[4] and HCC[5] preliminary flood risk assessment (PFRA) reports undertaken in accordance with the Flood Risk Regulations 2009[6] have been reviewed in undertaking this assessment.

2.3.2 LBHi has compiled evidence for a surface water management plan[7] but has not yet compiled a full surface water management plan or local flood risk management strategy (LFRMS). The BuCC draft LFRMS[8] is at the consultation stage and was published in February 2013. The HCC LFRMS[9] has been through consultation but has not yet been finalised.

2.3.3 The local planning authorities for the study area are LBHi, South Bucks District Council (SBDC) and Three Rivers District Council (TRDC). The local development framework

[3] Capita Symonds/Scott Wilson (2011), *London Borough of Hillingdon Preliminary Flood Risk Assessment.*
[4] Jacobs (2011), *Buckinghamshire County Council Preliminary Flood Risk Assessment.*
[5] Hertfordshire County Council (2011), *Hertfordshire County Council Preliminary Flood Risk Assessment.*
[6] *Flood Risk Regulations 2009* (SI 2009 No.3042). London, Her Majesty's Station Office
[7] Capita Symonds/Scott Wilson (2013), *Hillingdon Surface Water Management Plan Evidence Base.*
[8] Buckinghamshire County Council (2013), *Buckinghamshire County Council Local Flood Risk Management Strategy 2013 – 2018.*
[9] Hertfordshire County Council (2013), *Local Flood Risk Management Strategy for Hertfordshire 2013 – 2016.*

(LDF) core strategies were adopted for LBHi[10] in November 2012, SBDC[11] in February 2011 and TRDC[12] in October 2011. All three have supporting strategic flood risk assessment (SFRA) documents, however, none of the three councils have yet published a water cycle strategy though scoping has been undertaken for south-west Hertfordshire incorporating TRDC.

London Borough of Hillingdon Preliminary Flood Risk Assessment

2.3.4 The majority of LBHi lies within the Greater London indicative flood risk area; Harefield, Ickenham and Uxbridge, however, are excluded from the area. The LBHi PFRA supports this with the assessment concluding that flooding in these areas is unlikely to result in significant harmful consequences. It is recommended in the LBHi PFRA, however, that they are included in the London-wide assessment of flood risk to capture risks arising from elsewhere. The LBHi PFRA did not identify any significant historical flooding or future flood risks from non-fluvial sources within the study area.

London Borough of Hillingdon Surface Water Management Plan

2.3.5 The LBHi Surface Water Management Plan Evidence Base utilises detailed two-dimensional modelling of direct rainfall events to identify areas at significant risk of pluvial and surface water flooding and makes use of the Drain London mapping to identify critical drainage areas (CDA). The Proposed Scheme falls within a CDA at the far eastern extent of the Colne Valley viaduct; this, however, is directly related to the low level of the existing railway line which is in cutting at this point. The South Harefield CDA lies at the boundary extent of the study area. The Proposed Scheme, however, does not intersect with this CDA and therefore will not affect this pathway. The surface water management plan modelling showed a good correlation to the Environment Agency Flood Map for Surface Water (FMfSW) data.

Buckinghamshire County Council Preliminary Flood Risk Assessment

2.3.6 The BuCC PFRA confirms that there are no indicative flood risk areas of national significance within Buckinghamshire, consequently only Stage 1 of the Flood Risk Regulations 2009 process (i.e. the PFRA) has been completed.

2.3.7 The most significant historical flood event in Buckinghamshire was caused by high groundwater levels across the Chalk aquifers, resulting in high river flows and widespread groundwater flooding in the valleys of the Chiltern Hills. The flooding occurred in the winter of 2000/2001 and is considered in the BuCC PFRA to have had "significant harmful consequences".

2.3.8 The BuCC PFRA recognises that the construction and engineering of the Proposed Scheme may have a significant impact upon surface water flows. For example embankments and cuttings may, without suitable design solutions, impede the flow of small watercourses and surface runoff.

[10] London Borough of Hillingdon (2012), *Hillingdon Local Plan: Part 1 – Strategic Policies (Adopted November 2012).*
[11] South Bucks District Council (2011), *South Bucks Local Development Framework – Core Strategy Development Plan Document.*
[12] Three Rivers District Council (2011), *Local Development Framework – Core Strategy Submission.*

Buckinghamshire County Council Local Flood Risk Management Strategy

2.3.9 The BuCC LFRMS guides the planning process in relation to flood risk across all categories and outlines key policies in relation to development within Buckinghamshire. Specific policies of relevance to the Proposed Scheme are:

- "Policy 6 – the LLFA will seek to reduce the risk of flooding now in a way which does not compromise the interconnected needs of the economy, society and environment in the future"; and
- "Policy 15 – sustainable drainage systems (SuDS) should be used in new developments to reduce the rate and volume of surface water runoff. Design of SuDS to meet national standards and be adopted by the SuDS Approval Body. SuDS are expected to provide natural removal of pollutants and sediments, promote aquifer recharge, enhanced biodiversity, add aesthetic value and be easily maintainable."

Hertfordshire County Council Preliminary Flood Risk Assessment

2.3.10 The HCC PFRA confirms that although the London indicative flood risk area extends into Hertfordshire there are no indicative flood risk areas of national significance above the flood risk thresholds within Hertfordshire. Consequently, only Stage 1 of the Flood Risk Regulations 2009 process (i.e. the PFRA) has been completed.

2.3.11 The HCC PFRA considers flooding from surface water (direct runoff), groundwater and urban drainage to be of relevance in Hertfordshire. The HCC PFRA rules out canals and minor watercourses as posing no significant independent flood risks in the county. No historical events from surface water, groundwater or urban drainage were considered to be of sufficient severity to support further investigation.

Hertfordshire County Council Local Flood Risk Management Strategy

2.3.12 The HCC LFRMS guides the planning process in relation to flood risk across all categories and outlines key policies in relation to development within the county. At this stage, however, the HCC LFRMS policies area based solely on the Flood Risk Regulations 2009 and Flood and Water Management Act 2010 responsibilities and do not relate specifically to the management of flood risk. A set of high level objectives were put forward. Specific objectives of relevance to the Proposed Scheme are to:

- reduce the potential impact and costs of flooding in the county; and
- secure improvements to the water environment of Hertfordshire through the undertaking of actions associated with flood risk management.

Thames Region Catchment Flood Management Plan

2.3.13 The watercourses within CFA7 fall within the Thames Region Catchment Flood Management Plan (CFMP)[13] which covers the fluvial extent of the Thames basin. The main messages of the Thames Region CFMP revolve around the high risk of flooding to key urban centres, the majority of which lie downstream of the study area and the

[13] Environment Agency (2007), *Thames Region Catchment Flood Management Plan.*

predicted future increase in flood risk due to climate change. There is a high focus on managing and reducing existing flood risk in the basin through restoring and enhancing natural floodplain capacity and utilising the potential to manage floodwater through new developments especially within the upstream tributaries.

London Borough of Hillingdon Strategic Flood Risk Assessment

2.3.14 The LBHi SFRA[14] was completed in 2008 and provides an assessment of the various risks of flooding across the Borough. The FMfSW data and the Drain London mapping used in the LBHi Surface Water Management Plan supersede the LBHi SFRA assessment. Areas at risk of flooding from rivers, sewers and overland flow are described using detailed mapping. There is a risk of overland flow arising at the far eastern extent of CFA7 derived using the 'escarpment method'. The LBHi SFRA notes that there is a significant risk of groundwater flooding associated with the river terrace gravels along the Colne Valley. Several policy recommendations are proposed including the following policies specifically relevant to the Proposed Scheme:

- where floodplain storage is removed the development should provide compensatory storage on a level-for-level basis to ensure there is no loss in flood storage capacity; and
- an 8m buffer strip must be maintained along river corridors.

London Borough of Hillingdon Core Strategy

2.3.15 The LBHi Core Strategy was adopted in November 2012. Policy EM1 which covers adaptation to and mitigation against climate change is of specific relevance to flood risk and development, covering the following points:

- location and design of development to minimise the probability and impacts of flooding; and
- requirement for major development proposals to consider the whole water cycle impact which includes flood risk management, foul and surface water drainage and water consumption.

2.3.16 Policies EM3 and EM6 set out the position of the LBHi towards protection of environmental assets and flood risk management with a focus on maintaining watercourses and their settings for their biodiversity and recreational value, as well as incorporation of SuDS and water recycling schemes to holistically balance water usage and flood risk reduction. Policy EM3 specifically promotes the protection and creation of waterside open space known as the Blue Ribbon Network. The Colne Valley is identified as a strategic area of environmental opportunity.

South Bucks District Council Strategic Flood Risk Assessment

2.3.17 The SBDC SFRA[15] identifies the Colne Valley as an area of high flood risk and recommends a proactive approach in developments with developers encouraged to demonstrate a positive reduction in flood risk. There were no identified cases of historic flooding arising from sources other than the River Colne within the study area.

[14] Scott Wilson (2008), *London Borough of Hillingdon Strategic Flood Risk Assessment Level 1.*
[15] Jacobs (2008), *South Bucks District Council Strategic Flood Risk Assessment Level 1.*

South Bucks District Council Core Strategy

2.3.18 The SBDC Core Strategy was adopted in February 2011. It notes the presence of flood risk along the Colne Valley as well as historical instances of groundwater and urban drainage flooding. Core Policy 13 covers environmental management and restates the need for sequential testing to steer vulnerable development away from flood risk areas.

South West Hertfordshire Water Cycle Strategy

2.3.19 The South West Hertfordshire Water Cycle Strategy scoping study[16] (includes TRDC) identifies a risk of flooding from and pollution to the major aquifers along the Colne Valley where the chalk is overlain by thin alluvium soils and terrace gravels with high permeability. The use of infiltration-based SuDS along the Colne Valley is discouraged unless design is supported through detailed local site tests. The scoping study defers to the SFRAs for recommending and implementing flood risk management policies.

Three Rivers Strategic Flood Risk Assessment

2.3.20 The combined South West Hertfordshire SFRA[17] (includes TRDC) outlines the risks of flooding from all sources through the use of detailed mapping based on available information from the Environment Agency and British Geological Survey (BGS). The report reiterates the low probability of flooding arising from the GUC as an independent source on the basis that the canal embankments are generally low and in good condition with fairly short pounds, many double-gated locks and a high level of self-supported lateral water level controls. A number of policy recommendations are made including promoting a proactive approach from developers regarding flood risk management through reduction of flood risk and enhancement of river corridors. An assessment is made of the likely future changes to flood risk as a result of predicted climate change and it is found that, due to the large scale and mitigatory effect of the Colne Valley lakes, changes to the extents of flooding for the future scenario are not significant within the study area.

Three Rivers District Council Core Strategy

2.3.21 The TRDC Core Strategy was adopted in March 2011. Policy CP1 (Sustainable Development) recommends the use of SuDS as a flood risk management process, and discourages development in flood risk areas. The protection and enhancement of river corridors is also a priority under Policy CP9 (Green Infrastructure).

[16] Hyder Consulting (2010), *Dacorum Borough Council, St Albans City and District Council, Three Rivers District Council, Watford Borough Council, Welwyn Hatfield Borough Council Water Cycle Study – Scoping Study.*
[17] Halcrow Group (2007), *Dacorum Borough Council, St Albans City & District Council, Three Rivers District Council, Watford Borough Council Strategic Flood Risk Assessment Volume 1.*

3 Design criteria

3.1.1 It is a requirement of the design that the Proposed Scheme shall be protected against flooding from any source during the 1 in 1000 years return period (0.1% annual probability) rainfall event with water levels not rising closer than 1m to the top of rail level.

3.1.2 In accordance with the NPPF an allowance for climate change is included in the assessment by assuming that peak rainfall intensity will increase by 30% and that peak river flows will increase by 20%.

4 Data sources

4.1 Primary datasets

4.1.1 Consistent with the requirements of the NPPF this assessment considers the risk of flooding from rivers, direct surface water runoff, rising groundwater, overwhelmed drainage and sewer systems, and artificial sources such as reservoirs, lakes and canals.

4.1.2 The Proposed Scheme lies entirely outside the extent of flooding from the sea and therefore the risk of flooding from tidal sources is not considered in this assessment.

4.1.3 The primary datasets for each source of flooding used to assess the design elements are presented in Table 2. A high-level review of the risk of flooding and potential impacts is undertaken on the basis of these datasets across all flood sources. Where this review indicates potentially significant impacts on the risk of flooding, or a risk of flooding to the line, further investigation in the form of hydraulic modelling is undertaken.

Table 2: Flood risk assessment data sources

Source of flooding	Datasets reviewed	Data owner
Rivers	Flood zone mapping. Detailed River Network. Catchment hydraulic models.	Environment Agency
Surface water	FMfSW. Local surface water flood mapping.	Environment Agency LLFA
Groundwater	Areas susceptible to groundwater flooding. 1:50,000 geological mapping (superficial and bedrock). Potential for elevated groundwater.	BGS LLFA
Drainage and sewer systems	Sewer network plans. Lost river location plans.	Water companies (various) Local planning authority
Artificial sources	Reservoir inundation mapping (RIM) Canal infrastructure locations. Trunk water main asset plans.	Environment Agency Canal & River Trust Water companies (various)

4.2 Site familiarisation visits

4.2.1 Site familiarisation visits have been carried out for key locations along the route where access has been granted. A site familiarisation visit was undertaken in January 2013 to visit the area of proposed works across the Colne Valley and along the Newyears Green Bourne. The River Colne was visited with the Environment Agency and Natural England in August 2013 to discuss the hydrological and ecological aspects of the River Colne.

5 The proposed development

5.1 Topography and land use

5.1.1 The land use within CFA7 is characterised by its location between the suburban fringe of London and the Chiltern Hills. The dominant feature is the Colne Valley and the associated Colne Valley Regional Park, comprising a mix of protected water features associated with the area's strong gravel and aggregates extraction history. The water features are now used primarily for leisure activities and the intervening parcels of land are heavily wooded. There is still some on-going mineral extraction activity.

5.1.2 Away from the Colne Valley Regional Park the land use is predominantly arable farmland. The urban developments of Ickenham, Denham, Denham Green, South Harefield, Harefield and Maple Cross, however, extend into the study area. There are two golf courses to the south of the study area, and Denham Aerodrome is a prominent feature in the west.

5.2 Local flood risk receptors

5.2.1 The vulnerability of each local receptor with an identified pathway within the study area is presented in Table 3. The vulnerability is classified in accordance with the recommendations of Table 2 in the NPPF Technical Guidance Document and the Scope and Methodology Report (SMR) (see Volume 5: Appendix CT-001-000/1) and the SMR Addendum (see Volume 5: Appendix CT-001-000/2).

Table 3: Vulnerability of local receptors in CFA7

Local receptor	Description	Vulnerability classification	Source/pathway
Harefield Place Golf Club	Commercial leisure	Less vulnerable	Surface water 30 years - deep
Skip Lane industrial/builders area	Commercial/industrial	Less vulnerable	Surface water 200 years - shallow
Dews Farm	Residential dwelling and agriculture	More vulnerable	Groundwater moderate
Hillingdon Outdoor Activities Centre (HOAC)	Commercial leisure	Less vulnerable	Groundwater high Harefield No.3 Reservoir
The Alders	Residential dwelling	More vulnerable	Groundwater high
Lower Lodge	Residential dwelling	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - shallow Harefield No.3 Reservoir
The Buckinghamshire Golf Club	Commercial leisure	Less vulnerable	River flooding Flood Zone 2 Surface water 30 years - deep Groundwater high

Local receptor	Description	Vulnerability classification	Source/pathway
South Harefield village	Residential dwellings, commercial centre and leisure areas	More vulnerable	Surface water 30 years - deep Groundwater very high
Savay Lane residential dwellings	Residential dwellings	More vulnerable	River flooding Flood Zone 2 Surface water 30 years - deep Groundwater very high
Savay Farm	Residential dwelling and agriculture	More vulnerable	River flooding Flood Zone 2 Groundwater very high
Harefield Marina	Water-based leisure/commercial	Water compatible	Groundwater very high
Blackford pumping station and substation	Infrastructure	Essential infrastructure	River flooding Flood Zone 2 Groundwater very high
Denham Green and Denham Garden Village	Residential dwellings and urban area including school	More vulnerable	Surface water 30 years - deep Groundwater very high
Horse and Barge public house	Commercial, drinking establishment	More vulnerable	River flooding Flood Zone 2 Groundwater very high
Widewater Lock residential dwellings	Residential dwellings	More vulnerable	River flooding Flood Zone 2 Groundwater very high
Widewater Place	Commercial offices	Less vulnerable	Surface water 30 years - deep Groundwater very high
Denham industrial area	Denham Laboratories and Broadwater Park	Highly vulnerable	Surface water 30 years - deep Groundwater very high
Harleyford Aggregates	Broadwater Lake sand/gravel works	Water compatible	River flooding Flood Zone 3 Surface water 200 years - shallow Groundwater very high
Broadwater Farm substation	Infrastructure	Essential infrastructure	Groundwater very high
Broadwater Farm	Commercial (logistics)	Less vulnerable	Surface water 30 years - deep Groundwater very high
Denham Aerodrome	Transport infrastructure	Less vulnerable	Groundwater moderate
Technical Exponents and Fairthorpe	Commercial	Less vulnerable	Groundwater moderate
Roughwood and The Bungalow	Residential dwellings	More vulnerable	Groundwater moderate

Local receptor	Description	Vulnerability classification	Source/pathway
Denham Water Ski Club	Water-based leisure	Water compatible	River flooding Flood Zone 3 Surface water 200yr - shallow Groundwater very high
Weybeards Cottages substation	Infrastructure	Essential Infrastructure	Surface water 200 years - shallow Groundwater very high
Denham aerodrome north commercial area	Commercial	Less vulnerable	Groundwater moderate
Denham Manor nursing home	Residential care home	More vulnerable	Groundwater moderate
Weybeards cottages pumping station	Infrastructure	Essential Infrastructure	River flooding Flood Zone 2 Groundwater very high
Denham Park Farm and March Cottage	Residential dwellings	More vulnerable	Surface water 30 years - deep
Marish Farm residential area	Residential dwellings including mobile homes	Highly vulnerable	Groundwater moderate
Oakwood House and Middle Halings	Residential dwellings	More vulnerable	Groundwater moderate
Broadwater Sailing Club	Water-based leisure	Water compatible	River flooding Flood Zone 3 Groundwater very high Hilfield Park reservoir
Weybeards Cottages	Residential dwellings	More vulnerable	River flooding Flood Zone 2 Surface water 200 years - shallow Groundwater very high
Black Jacks Lock residential dwellings	Residential dwellings	More vulnerable	Groundwater very high Hilfield Park reservoir
Troy House and West Hyde House	Residential dwellings	More vulnerable	River flooding Flood Zone 2 Surface water 30 years - shallow Groundwater very high Hilfield Park reservoir
Batchworth Dragon Boat Club and Rickmansworth Sailing Club	Water-based leisure	Water compatible	River flooding Flood Zone 3 Surface water 200 years - shallow Groundwater very high Hilfield Park reservoir

Local receptor	Description	Vulnerability classification	Source/pathway
Jacks Lane	Residential dwellings	More vulnerable	Surface water 30 years - deep Groundwater very high Hilfield Park reservoir
Troy Wharf industrial area	Commercial/industrial units	Less vulnerable	River flooding Flood Zone 3 Groundwater very high Hilfield Park reservoir
Colne Cottage	Residential dwelling	More vulnerable	River flooding Flood Zone 2 Groundwater very high
Clancy Docwra	Construction company	Less vulnerable	River flooding Flood Zone 3 Groundwater very high
West Hyde village	Residential dwellings and playing fields	More vulnerable	River flooding Flood Zone 2 Surface water 30 years - deep Groundwater very high Hilfield Park reservoir
Coppermill pumping station and substation	Infrastructure	Essential infrastructure	River flooding Flood Zone 2 Surface water 200 years - shallow Groundwater very high Hilfield Park reservoir
Sunnyhill Road	Residential dwellings	More vulnerable	Groundwater moderate
Maple Cross village	Residential dwellings, including Maple Cross school	More vulnerable	Surface water 30 years - deep Groundwater very high

5.3 Description of the Proposed Scheme

5.3.1 The Proposed Scheme through the Colne Valley area will be approximately 5.7km in length. It will commence from the boundary of the existing Harvil Road alignment, north of Ickenham and will proceed north-west on a viaduct through the Colne Valley, passing west of South Harefield and east of Denham Green, over the GUC, Mid Colne Valley Site of Special Scientific Interest, River Colne, a number of lakes and A412 Denham Way/North Orbital Road. The route will then continue in a north-west direction passing west of West Hyde in a series of cuttings and embankments before entering the Chiltern tunnel via the Chiltern tunnel south portal.

5.3.2 The route will leave CFA6 and the London Metropolitan design area at grade, immediately rising onto embankment approaching the Colne Valley viaduct, as shown

on Map CT-06-19 to Map CT-06-21 (Volume 2, CFA7 Map Book). Harvil Road will be realigned to pass over the Proposed Scheme via an overbridge.

5.3.3 The Ickenham auto-transformer feeder station[18] will be located just west of Harvil Road, to the south of the Proposed Scheme, with an associated access from Harvil Road. This is located mainly in the Colne Valley area and partly within CFA6.

5.3.4 A new National Grid feeder station located approximately 250m north-east of the Proposed Scheme and 350m north-east of the HOAC, with associated access track from Harvil Road.

5.3.5 The Proposed Scheme will pass onto the 3.4km long Colne Valley viaduct to completely span the Colne Valley Regional Park and River Colne floodplain between 11m to 15.5m above the ground/water level. The viaduct will carry the Proposed Scheme over the Colne Valley, passing above the Harefield No.2 Lake, GUC, Savay Lake, Moorhall Road, Korda Lake, Long Lake, the River Colne and the A412 Denham Way/North Orbital Road. A realignment of the River Colne will be required to avoid placing viaduct piers within the channel, as shown on Map CT-06-20, C5 (Volume 2, CFA7 Map Book).

5.3.6 The Proposed Scheme will continue north-west from the Colne Valley north embankment and enter the Tilehouse Lane cutting which will be up to 11m deep. It will then continue onto the West Hyde embankment and enter the Chiltern tunnel south cutting which will be up to 22m deep. From the Chiltern tunnel south cutting, the Proposed Scheme will continue north-west into the Chiltern tunnel south portal run in the tunnel for approximately 100m before leaving this area.

[18] HS2 trains will draw power from overhead power line, requiring feeder stations and connections to the 400kV National Grid network. In addition to feeder stations, smaller auto-transformer stations will be required at more frequent intervals. One National Grid feeder station, one feeder station and one auto-transformer station will be required in the local area.

6 Existing flood risk

6.1 Historical flooding incidents

6.1.1 The LBHi PFRA shows that historical flooding occurred on the River Colne downstream of the Proposed Scheme crossing location. The Three Rivers SFRA shows isolated areas of river flooding adjacent to the River Colne in 1987 approximately 1km upstream of the Proposed Scheme crossing location. No further river flooding events are shown within this study area.

6.1.2 Within LBHi there are no historical surface water or groundwater flooding incidents in the study area. According to the BuCC PFRA there are historical records of surface water flooding in Denham Green in 2001 and 2003.

6.2 Risk of flooding from rivers

6.2.1 Within CFA7, the Proposed Scheme will cross the floodplain of the River Colne, as shown on Map WR-01-008 (Volume 5, Water Resources and Flood Risk Assessment Map Book). A number of watercourses will be crossed within the Colne floodplain, including the Newyears Green Bourne (SWC-CFA7-02), the GUC (SWC-CFA7-01) and the River Colne (SWC-CFA7-03). The GUC and River Colne are connected by a series of lateral weirs.

6.2.2 The Proposed Scheme will cross the full width of the Colne floodplain on the Colne Valley viaduct which will be 3.4km in length. The floodplain is wide and the viaduct will also cross the former gravel pit lakes Harefield No.2 Lake, Savay Lake, Korda Lake, Long Pond and Harefield Moor Lake. Due to the alignment of the proposed viaduct as well as structural constraints on the maximum span width it will be necessary to re-align the channel of the River Colne to avoid placing viaduct piers within the river.

6.2.3 The Newyears Green Bourne (SWC-CFA7-02) has a catchment size of approximately 5km^2 at the intersection with the Proposed Scheme which will be approximately 300m upstream of where the watercourse outfalls into Harefield No.2 Lake. The Proposed Scheme will cross approximately 250m and 270m of Flood Zones 3 and 2 respectively at the valley crossing of the Newyears Green Bourne and 390m of Harefield No.2 Lake that is included in the outline of both flood zones. The Newyears Green Bourne continues south along the eastern side of the raised embankment of the GUC (SWC-CFA7-01) and joins the River Colne downstream of the aqueduct at Denham Lock some 2km downstream of the Proposed Scheme crossing.

6.2.4 The River Colne (SWC-CFA7-03) has a catchment size of approximately 725km^2 at Moorhall Road. The Proposed Scheme will cross (on viaduct) approximately 1.1km of Flood Zone 3 and 1.3km of Flood Zone 2 (including Savay Lake, Korda Lake, Long Pond and Harefield Moor Lake) as well as the GUC which is approximately 30m wide and is designated as Flood Zone 2.

6.2.5 The flood zone mapping does not show any above ground connection between the River Colne to the west of the GUC and the Newyears Green Bourne to the east of the GUC at either the 100 year return period (1% annual probability) flood or the 1,000

year return period (0.1% annual probability) flood until Denham Lock. The lakes to the south are also shown to lie within Flood Zone 3. It is reasonable to assume, therefore, that the floodplain of the Newyears Green Bourne, as well as the water level in Harefield No.2 Lake, is not directly affected by flood water levels in the River Colne. In addition, there is no connection between the GUC area of Flood Zone 2 and the River Colne to the west shown between Black Jack's Lock (approximately 1.5km upstream of the Proposed Scheme) until downstream of the existing Chiltern Railway embankment. There may, however, be connectivity between the two floodplains arising due to the permeable river terrace deposits of the superficial geology and bedrock aquifers beneath. It may be expected that sustained water levels would be similar, particularly in the lakes, on both sides of the GUC during periods of prolonged flooding due to the highly permeable subsurface geology and the influence of groundwater.

6.2.6 The flood zone mapping is based on detailed hydraulic modelling of the River Colne undertaken by Halcrow on behalf of the Environment Agency in 2010. Although the model is a linked one-dimensional channel, two-dimensional floodplain model the study area is represented as one-dimensional channel flow with reservoir units to represent the lakes. The main disadvantage of this representation is that a high level of bypassing via the lakes could result in an underestimate of upstream flood water levels, as the reservoir unit will work to equalise water levels along the length of the river reach to which it is connected without reference to conveyance times within the floodplain. Nevertheless, due to the flat gradient of the river and the high degree of storage available within the floodplain the representation used is considered to be hydraulically appropriate to obtain peak flood water levels. Time-varying results have been treated with caution.

6.2.7 The model results show very low flood flow volumes through the model within the study area. Flood flows for the 1 in 100 years and 1 in 1,000 years return period (1% and 0.1% annual probability) events, estimated using catchment descriptors and the Revitalised Flood Hydrograph (ReFH) rainfall runoff methodology method for the River Colne at Moorhall Road, are 132m^3/s and 237m^3/s although this figure does not include any allowance for floodplain and lake storage and attenuation. Corresponding flows in the river channel taken from the hydraulic model are 32m^3/s and 127m^3/s. Floodplain flow results were not provided, however comparison of the 1 in 100 years return period (1% annual probability) flood level in the reservoir unit representing Savay Lake suggests that flood waters do not overtop Moorhall Road in this event and hence all flow passes along the channel. Overtopping does occur in the 1 in 1,000 years return period (0.1% annual probability) event and since full results have not been provided, it is not possible to quantify this flow. In view of the large discrepancy between the basic ReFH analysis of flood flows and the modelled flood flows a review of the hydrological and hydraulic modelling was undertaken to determine confidence in the flood zone outlines.

6.2.8 The hydraulic modelling report[19] for the River Colne includes a detailed hydrological study. Peak flood flows were derived using the latest Flood Estimation Handbook

[19] Halcrow Group (2010), *Upper Colne SFRM Study (TH013 and TH031) Hydraulic Modelling and Mapping Final Technical Report.*

(FEH) statistical method to determine the median flow (QMED - 1 in 2 years return period (50% annual probability) flood flow) followed by the application of a growth curve derived using single site analyses at the various flow gauges along the River Colne. A full local ReFH rainfall runoff analysis using rain gauge and flow gauge data to calibrate the various unit hydrograph parameters was also undertaken during the modelling process. The ReFH hydrographs were scaled using the statistical peak flow and applied to the ReFH boundaries used as inflows in the hydraulic model. The methodology used to determine design flood flows is robust and uses detailed flow gauge data to define the runoff and routing parameters. In addition, the model was calibrated using observed rainfall events, and flood flows at Denham gauge were actually found to be overestimated for the four storms studied. Flood water levels were also overestimated relative to observed flood water levels indicating that the model is conservative.

6.2.9 Although significant discrepancies exist between design flood flows derived using a theoretical ReFH analysis and the calculated flows in the hydraulic model the methodology used to derive design inflows to the hydraulic model is robust and based on observed data. In addition, the modelled flood flows in the watercourse are based on observed rainfall events and match well to flow gauge records at Denham even erring on the conservative side in overestimating both flows and water levels. The results of the Environment Agency hydraulic modelling can therefore be used for the analysis of flood risk to the Proposed Scheme with a relatively high level of confidence.

6.2.10 Design elements within the Proposed Scheme that will be at risk of flooding from the Newyears Green Bourne and River Colne are the Colne Valley viaduct and the Ickenham National Grid feeder station.

Flood risk to the Proposed Scheme

6.2.11 To the east of the GUC, flood water levels are dictated by the Newyears Green Bourne. The Environment Agency has not provided a hydraulic model for the Newyears Green Bourne. A conceptual model was created within InfoWorks RS (version 13.5.1) to assess the effect of the viaduct on flood levels using a fixed downstream boundary level and ReFH inflows. Cross sections were produced from light detection and ranging (LiDAR) data. The maximum water level within Savay Lake was extracted from the Environment Agency model of the River Colne and applied as the water level in Harefield No.2 Lake. This level was then applied as the downstream boundary and was run for the 1 in 1000 years return period (0.1% annual probability) and 1 in 100 years return period (1% annual probability) flood flows. Modelled flood water levels at the crossing of the Newyears Green Bourne are presented in Table 4.

6.2.12 The minimum top of rail level across the Newyears Green Bourne valley will be 47.7m above Ordnance Datum (AOD), over 10m above the modelled 1 in 100 years return period (0.1% annual probability) flood water level. Across Harefield No.2 Lake the minimum top of rail level will be 48.6m AOD, a further metre above flood water levels.

Table 4: Newyears Green Bourne model results

	1% annual probability flood	1% annual probability including climate change allowance	0.1% annual probability flood
Peak channel flow	6.3m^3/s	7.6m^3/s	12.5m^3/s
Modelled flood level	37.08m AOD	37.10m AOD	37.27m AOD
Harefield No.2 Lake (downstream condition)	36.12m AOD	36.17m AOD	37.20m AOD

6.2.13 The Proposed Scheme will be at least 1m above the 1 in 1,000 years return period (0.1% annual probability) flood water level in the Newyears Green Bourne and Harefield No.2 Lake. As a result, the risk of river flooding on the operational portion of the Proposed Scheme will be less than 0.1%.

6.2.14 The Newyears Green Bourne is culverted through farmland for some 1.2km from Middle Lodge (downstream of Breakspear Road North) to Newyears Green Lane. The upstream end of the culverted section is approximately 2km upstream of the Proposed Scheme. The Environment Agency flood zone mapping shows an area of floodplain that passes directly south-west along a natural valley and diverges from the route of the watercourse which flows south at this location as shown on Map WR-01-008 (Volume 5, Water Resources and Flood Risk Assessment Map Book). This dry valley continues parallel to the access road to Middle Lodge, past Lower Lodge and across Harvil Road. The flood zone maps show the area of flooding ending 500m downstream of Harvil Road, however, LiDAR information suggests that any flooding will continue to flow overland and discharge to Harefield No.2 Lake a further 200m downstream. The Ickenham National Grid feeder station will be located within Flood Zone 3.

6.2.15 The south eastern extent of the Ickenham National Grid feeder station is located within the area at risk of flooding. As set out in the NPPF inappropriate development in areas at risk of flooding should be avoided. Development should be directed away from areas at highest risk. Where development is necessary it should be made safe without increasing flood risk elsewhere. On the basis that the Ickenham National Grid feeder station has to be located partially in Flood Zone 3 for operational reasons, it is considered essential infrastructure.

6.2.16 Essential infrastructure is permitted in Flood Zone 3 provided the development passes the Exception Test which states that:

- "it must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment where one has been prepared; and
- a site-specific flood risk assessment must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users without increasing flood risk elsewhere and, where possible, will reduce flood risk overall."

6.2.17 Mitigation measures and flood resilience measures will be incorporated into the feeder station to ensure that there is no increase in flood risk elsewhere and that the feeder station is safe. These flood resilience and mitigation measures are described in section 7 of this report. The Proposed Scheme will result in wider sustainability benefits which are detailed in the route-wide appendix (Volume 5: Appendix WR-001-000). On this basis the feeder station passes the Exception Test.

6.2.18 West of the GUC where water levels are dictated by the River Colne the baseline estimates of maximum flood water levels have been extracted from the Environment Agency model. Design flood water levels extracted from the model at each relevant location are presented in Table 5.

Table 5: River Colne model details

	1% annual probability flood	1% annual probability including climate change allowance	0.1% annual probability flood
Peak channel flow	32.4m^3/s	38.3m^3/s	126.8m^3/s
Channel flood level (crossing location)	37.83m AOD	37.89m AOD	38.23m AOD
Savay Lake flood level	36.12m AOD	36.17m AOD	37.20m AOD
Korda Lake flood level	36.56m AOD	36.67m AOD	37.72m AOD

6.2.19 The top of rail level at the channel crossing will be 51.7m AOD. Across Savay Lake the minimum top of rail level will be 49.5m AOD and across Korda Lake the minimum top of rail level will be 50.4m AOD. There will therefore be a minimum freeboard of 11.8m between the 1 in 1,000 years return period (0.1% annual probability) flood water level and the minimum top of rail level, at the south-eastern extent of Savay Lake. As a result the risk of river flooding on the operational portion of the Proposed Scheme will be less than 0.1%. There are no other elements to the Proposed Scheme that will potentially be at risk of flooding.

6.3 Risk of flooding from surface water

Colne Valley viaduct

6.3.1 The FMfSW shows a number of scattered areas at risk of various levels of flooding including areas of deep (greater than 300mm in depth) flooding during the 1 in 30 years return period (3.3% annual probability) rainfall event along both the Newyears Green Bourne and River Colne valleys. All areas shown to be at risk lie within the extents of flooding from rivers discussed in Section 6.2 of this report. The Proposed Scheme will be a minimum of 11m above existing ground levels for the entire length of the Colne Valley viaduct. There will be no significant risk of flooding arising to this section of the Proposed Scheme from direct surface water runoff.

Old Shire Lane

6.3.2 Approximately 1km south-east of the M25, near the Old Shire Lane Circular Walk, the Proposed Scheme will intersect with the confluence of several dry valleys arising from the hills to the west of the Proposed Scheme as shown on Map WR-01-008, C5

(Volume 5, Water Resources and Flood Risk Assessment Map Book). A design element within the area shown to be at risk is the Chiltern tunnel south approach embankment.

6.3.3 Four separate valleys combine at the crossing location to follow a single flow path north-east towards Tilehouse Lane and the River Colne. The LiDAR information for the area suggests that these valleys incorporate significant flood catchments with the northern-most valley arising some 4km upstream of the Proposed Scheme crossing near Chalfont St Giles. The FEH CD-ROM indicates a total catchment size for the four valleys at the Proposed Scheme crossing of 6.9km^2 with resultant potential flood flow volumes in the 1 in 200 years return period of 0.9m^3/s. The catchment descriptors suggest high infiltration rates, which, when combined with low rainfall in the area, lead to comparatively low runoff rates given the total catchment size. This is consistent with the highly permeable soils characteristic of this area.

6.3.4 Comparison of the FMfSW outlines with the LiDAR data for the area suggests a 1 in 200 years return period (0.5% annual probability) flood water level of 47m AOD at the confluence crossing. The Proposed Scheme will pass along the base of the northern dry valley for approximately 600m with flood water levels around 54m AOD at the northern extent of the combined valley crossing. Corresponding Proposed Scheme top of rail levels will be 55.8m AOD rising to 56.9m AOD. The Proposed Scheme top of rail level will therefore be a minimum of 2.9m above the 1 in 200 years return period (0.5% annual probability) flood water level.

6.4 Risk of flooding from groundwater

6.4.1 Figure F.1 in the BuCC PFRA and Figure 3 in the HCC PFRA show that there are areas that have a susceptibility to groundwater flooding within the study area. The most notable areas are:

- within the valley of the River Colne where more than 75% of the area is shown to be susceptible to groundwater flooding; and
- within the dry valleys at Old Shire Lane where the Chalk aquifer is unconfined and approximately 50% of the area is susceptible to groundwater flooding.

6.4.2 The LBHi PFRA confirms that there is an increased potential for elevated groundwater within the valley of the River Colne within the borough.

6.4.3 These areas are confirmed in the BGS susceptibility to groundwater flooding dataset.

6.4.4 For there to be a risk of flooding from groundwater, the relevant receptor needs to be below ground or at the surface. Consequently, where the Proposed Scheme is raised above surrounding ground, either on embankment or viaduct, the risk of flooding from groundwater is negligible. The Colne Valley viaduct and Chiltern tunnel south approach embankment will both span the areas of risk above ground level.

6.5 Risk of flooding from drainage systems

6.5.1 The LBHi PFRA reports that there have been one to five historical records of sewer flooding within the study area (as of June 2010). The BuCC PRFA reports that there

have been no recorded incidents of sewer flooding within the study area. There is not sufficient localised information for sewer flooding in the HCC PFRA to be able to identify historical records within the study area.

6.5.2 The Proposed Scheme will not pass through any urban areas within the study area and there will consequently be no significant risk of flooding from drainage systems.

6.6 Risk of flooding from artificial sources

Reservoirs

6.6.1 The Environment Agency RIM displays the residual risk of failure of artificial water bodies with a capacity above 25,000m^3 which are considered under the Reservoirs Act 1975[20] (as amended by the Flood and Water Management Act 2010[21]). This requires water companies to maintain their reservoirs such that the annual probability of a breach of the reservoir is 1 in 50,000. Although there is a potential impact on the residual risk of flooding from the reservoir, the likelihood of such flooding occurring is extremely low.

6.6.2 The Proposed Scheme will cross the area shown to be at risk in the event of failure of the Harefield No.3 covered reservoir at Harefield No.2 Lake, as shown on Map WR-01-008, G5 (Volume 5, Water Resources and Flood Risk Assessment Map Book). Flooding would follow the Newyears Green Bourne and then the natural dry valley between Bayhurst Wood Country Park and Harefield No.2 Lake. The reservoir is located approximately 4km upstream of the Proposed Scheme, north-east of Harefield. The Proposed Scheme will cross the area of risk at Harefield No.2 Lake, which is the downstream extent of the area at risk and lies within the extents of Flood Zone 3 in the area of the Proposed Scheme. The area of risk lies along the dry valley to the north of the Newyears Green Bourne and covers a greater area than the Flood Zone extents at the Ickenham National Grid feeder station. Consequently, there is an additional risk of flooding to the National Grid feeder station from this source.

6.6.3 The Proposed Scheme will also fall within the area shown to be at risk in the event of a breach of the Hilfield Park reservoir embankment with flooding occurring via the Hilfield Brook and River Colne, as shown on Map WR-01-008, E5 (Volume 5, Water Resources and Flood Risk Assessment Map Book). The reservoir is located approximately 20km upstream of the Proposed Scheme, near Borehamwood and the Proposed Scheme will cross the area of risk at the far downstream extent. At the crossing location the extent of the area at risk is confined to the river channel. Consequently, it is expected that flooding in the vicinity of the Proposed Scheme would take the form of slightly elevated flood flows and levels within the River Colne.

6.6.4 At both locations the Proposed Scheme will cross the area of risk at the far downstream extent of the area of influence where water levels in the respective water bodies - Harefield No.2 Lake and River Colne - would be relatively unaffected. The extents of flooding shown are well within the corresponding river and surface water flood risk extents of the Newyears Green Bourne and River Colne. The Colne Valley

[20] *Reservoirs Act 1975* (c.23). London, Her Majesty's Stationery Office.
[21] Flood and Water Management Act 2010 (c.29). London, Her Majesty's Stationery Office.

viaduct will be a minimum of 10.3m above existing ground levels and 5.7m above 1 in 1,000 years return period (0.1% annual probability) river flood water levels. Consequently, there will not be a significant risk of flooding to the Proposed Scheme arising from failure of the Harefield No.3 or Hilfield Park reservoirs.

6.6.5 Although the probability of flooding due to reservoir failure is very low, the consequences of flooding are potentially significant.

Colne Valley gravel pit lakes

6.6.6 The gravel pit lakes situated along the Colne Valley are all at or below existing ground levels and consequently there is no risk of flooding associated with them except in combination with flooding from the River Colne.

Grand Union Canal

6.6.7 The Three Rivers SFRA report reiterates the low probability of flooding arising from the GUC (SWC-CFA7-01) as an independent source on the basis that the canal embankments are generally low and in good condition, with fairly short pounds, many double-gated locks and a high level of self-supported lateral water level control.

6.6.8 As part of the Three Rivers SFRA, British Waterways (now the Canal & River Trust) was consulted to determine the potential for breach and overtopping of the canal. The Canal & River Trust indicated that risk of breach in the canal is extremely low for the following reasons:

- "the significant number of connections between the canal and river via numerous large weir structures. As such water levels within the canal are controlled and overtopping is highly unlikely to occur;
- along most of its course the canal is raised slightly above the river and therefore any water overtopping from the canal would be discharged into the river;
- where the rivers and canal are at similar levels and are in close proximity to one another, the area between them is naturally wet encouraging the growth of watercress, which provides storage for any water discharged from either water body;
- there are no canal embankments with a high probability or consequence of failure as defined by the Canal & River Trust. All canal embankments in the study area have a designated low/medium risk of failure;
- there are no major control sluices other than a large flood control structure at Batchworth; and
- there are a large number of locks and fairly short pounds throughout the canal system. As such any break outs would be expected to be contained within the canal. Significant flooding could only occur if two lock gates were to fail simultaneously which is unlikely given that no such failures have occurred in the UK over the last 200 years."

6.6.9 Even given the extremely low probability of failure or overtopping, due to the high number of connections between the GUC and the River Colne within the study area as well as the high storage capacity of the lakes and floodplain, any flooding arising from

this source is likely to be collected and discharged via the lakes and river with flood extents contained within the extent of river flooding.

6.6.10 The overall risk of flooding to the Proposed Scheme from the GUC is negligible.

6.7 Summary of baseline flood risk

Table 6: Summary of baseline flood risk for all sources of flooding in CFA7

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
River	Newyears Green Bourne	Very High Flood Zone 3a	Colne Valley viaduct	Top of rail level will be >1m above 1000 years return period water level.
River	River Colne	Very High Flood Zone 3b		
River	Overland from Newyears Green Bourne	Very High Flood Zone 3a	Ickenham auto-transformer feeder station	Ickenham auto-transformer feeder station will be within Flood Zone 3 – at risk.
Surface Water	Various within Newyears Green Bourne and River Colne valleys	High 30 years FMfSW >0.3m	Colne Valley viaduct	Top of rail level will be>1m above ground level.
Surface Water	Old Shire Lane	High 30 years FMfSW >0.3m	Chiltern tunnel south approach embankment	Top of rail level will be >1m above ground level.
Artificial	Harefield No.3 Reservoir	Low Within inundation mapping extent	Colne Valley viaduct	Top of rail level will be >1m above maximum flood water level.
			Ickenham auto-transformer feeder station	Ickenham auto-transformer feeder station will be within inundation mapping extent – at risk.
Artificial	Hilfield Park Reservoir	Low Within inundation mapping extent	Colne Valley viaduct	Top of rail level will be >1m above maximum flood water level.

7 Flood risk management measures

7.1 Risk of flooding from rivers

7.1.1 At all flood zone crossings replacement floodplain storage will be provided as near to the source of the impact as possible for all losses in floodplain storage including viaduct piers, embankments and all associated development. Specific mitigation is outlined below.

Newyears Green Bourne

7.1.2 Conceptual modelling of the Newyears Green Bourne suggests that the Proposed Scheme will result in a moderate afflux (less than 100mm) due to viaduct piers within the floodplain and the encroachment of the Colne Valley south embankment into the southern floodplain extent. Replacement floodplain storage will be provided upstream of Harvil Road as part of a holistic mitigation solution to include both the Colne Valley viaduct and the Harvil Road diversion (discussed in Volume 5: Appendix WR-003-006) crossings of the Newyears Green Bourne.

7.1.3 The detailed design of the realignments will be completed in consultation with the Environment Agency to meet their objectives with respect to hydraulic capacity, flood risk, ecology and hydromorphology. Where reasonably practicable, the permanent channel realignments will be constructed in advance of other activities associated with the viaduct construction.

7.1.4 The Ickenham National Grid feeder station is located in Flood Zone 3. Flood resilient measures will be incorporated into the feeder station in order to prevent flooding of the infrastructure as follows:

- ground levels will be raised 1m above the 1 in 1000 year flood water level;
- ground profiling around the raised feeder station will be contoured to ensure floodwater continues to be conveyed downstream within the same valley; and
- replacement floodplain storage will be provided to ensure that the ground raising within the floodplain does not increase flood risk elsewhere.

River Colne

7.1.5 The flooding mechanics of the River Colne along the Colne Valley country park are characterised by high energy in-channel flood flows and contrasting level-pool effects within the large lakes forming the floodplain. It is necessary to realign the River Colne where the route crosses on viaduct.

- the length of the realignment has been limited to approximately 170m to maximise the retention of the existing channel;
- the realignment enables the channel to pass between two of the piers within the viaduct. This avoids an increase in flood risk which would have arisen had a pier been placed in the channel;
- to address any potential increase in flood risk the Proposed Scheme includes replacement floodplain storage and channel improvement works to offset this

impact; and

- replacement floodplain storage areas will be provided at the edge of the modelled floodplain of the River Colne to mitigate loss of floodplain storage resulting from permanent structures in the floodplain such as piers. Two locations for replacement floodplain storage have been identified as shown on Map CT-06-019 and CT-06-020 (Volume 2, CFA7 Map Book).

7.1.6 Construction of the jetty across the River Colne will require other mitigation to ensure a negligible impact on the risk of flooding during the construction period. Measures could include:

- the sequencing of construction;
- the pile spacing and location;
- setting the height of the jetty to take into consideration the risk of flooding from the River Colne;
- temporarily widening the River Colne channel whilst the jetty is in place over the watercourse;
- use of a temporary by-pass; and
- incorporating the selected measures in the flood risk management plan to be submitted as required by Section 16 of the draft Code of Construction Practice (Volume 5: Appendix CT-003-000).

7.2 Risk of flooding from surface water

7.2.1 In all cases where surface water flood flows will be intercepted by the Proposed Scheme floodwaters will be collected in land drainage and conveyed beneath the Proposed Scheme in culverts thus maintaining flood pathways. Potential increases in peak discharge rates will be attenuated prior to release back into the natural drainage network.

7.2.2 The FMfSW shows the extent of flooding due to rainfall that would occur prior to collection of water into streams or designated drainage infrastructure. By collecting the flows from the dry valley into an adequately designed land drainage system, the Proposed Scheme will effectively remove the risk of surface water flooding from the point at which the flow would be intercepted for all return period events up to and including 100 years (>1% annual probability rainfall events) including an allowance for climate change. There is a residual risk of the cut-off drain overtopping in more extreme events.

7.2.3 Measures to manage the risk of flooding from surface water runoff include:

- provision of replacement floodplain storage and surface water attenuation facilities to restrict peak surface water runoff rates to existing greenfield rates;
- culverts have been designed with adequate capacity to convey the 1 in 100 years (1% annual probability) flow including an allowance for climate change; and

- design of culverts with internal 600mm freeboard and 300mm allowance for siltation to minimise the chances of blockage or future capacity restrictions.

7.3 Risk of flooding from groundwater

7.3.1 There are no locations where the top of rail level of the Proposed Scheme will be below ground level in an area shown to be at risk of flooding from groundwater. Therefore no risk of flooding to the Proposed Scheme is expected and no specific mitigation will be required.

7.3.2 There will not be any significant impact on the risk of flooding from groundwater arising from the Proposed Scheme and therefore no specific mitigation will be required.

7.4 Risk of flooding from drainage systems

7.4.1 There will be no risk of flooding from drainage systems to the Proposed Scheme, nor any anticipated effects on the risks of flooding from drainage systems within the study area arising from the Proposed Scheme. Therefore, no specific mitigation will be required.

7.5 Risk of flooding from artificial sources

7.5.1 Potential flood water levels and extents arising as a result of breach of the Harefield No.3 and Hilfield Park Reservoirs will be less than river flooding from the Newyears Green Bourne and River Colne respectively. Replacement floodplain storage provided to mitigate the potential effects of the viaduct on the risk of flooding from rivers will serve to offset any potential effects on the severity of flooding from this source. Due to the extremely low probability of such flooding occurring, and the likely low significance of any impacts arising from the Proposed Scheme, it is not considered necessary to provide additional mitigation for this scenario.

8 Post-development flood risk assessment

8.1 Local receptors

8.1.1 In addition to the risk of flooding that exists to the Proposed Scheme, there is potential for the Proposed Scheme to affect the risk of flooding to third party receptors by altering flow mechanics across the range of flood sources. All local receptors with a potential flood risk are identified in Section 5 of this report. For the Proposed Scheme to have an impact on a given receptor the identified pathway for that receptor must be shared by both the subject receptor and the Proposed Scheme with the result that a number of cases can be excluded immediately. Table 7 summarises the shared pathways between the Proposed Scheme and each receptor and identifies cases where no shared pathway exists.

Table 7: Shared flood risk pathways in CFA7

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Harefield Place Golf Club	Less vulnerable	Surface water 30 years - deep	No shared pathway.
Skip Lane industrial/builders area	Less vulnerable	Surface water 200 years - shallow	No shared pathway.
Dews Farm	More vulnerable	Groundwater moderate	No significant below ground construction will be within shared risk area. No shared pathway.
HOAC	Less vulnerable	Groundwater high Harefield No.3 Reservoir	Colne Valley viaduct will be at this location.
The Alders	More vulnerable	Groundwater high	No significant below ground construction will be within shared risk area. No shared pathway.
Lower Lodge	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - shallow Harefield No.3 Reservoir	Colne Valley viaduct will be 700m downstream. Ickenham auto-transformer feeder station is 500m downstream.
The Buckinghamshire Golf Club	Less vulnerable	River flooding Flood Zone 2 Surface water 30 years - deep Groundwater high	Chiltern Main Line embankment will be between the Proposed Scheme and receptor. No shared pathway.
South Harefield village	More vulnerable	Surface water 30 years - deep Groundwater very high	No shared pathway.

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Savay Lane residential dwellings	More vulnerable	River flooding Flood Zone 2 Surface water 30 years - deep Groundwater very high	Colne Valley viaduct will be both upstream and downstream in floodplain, on opposite bank.
Savay Farm	More vulnerable	River flooding Flood Zone 2 Groundwater very high	Colne Valley viaduct will be both upstream and downstream in floodplain, on opposite bank.
Harefield Marina	Water compatible	Groundwater very high	There will be no significant below ground construction within shared risk area. No shared pathway.
Blackford pumping station and substation	Essential infrastructure	River flooding Flood Zone 2 Groundwater very high	Colne Valley viaduct will be at this location.
Denham Green and Denham Garden Village	More vulnerable	Surface water 30 years - deep Groundwater very high	No shared pathway.
Horse and Barge public house	More vulnerable	River flooding Flood Zone 2 Groundwater very high	Colne Valley viaduct will be in the floodplain between the River Colne and this receptor.
Widewater Lock residential dwellings	More vulnerable	River flooding Flood Zone 2 Groundwater very high	Colne Valley viaduct will be in the floodplain between the River Colne and this receptor.
Widewater Place	Less vulnerable	Surface water 30 years - deep Groundwater very high	No shared pathway.
Denham industrial area	Highly vulnerable	Surface water 30 years - deep Groundwater very high	No shared pathway.
Harleyford Aggregates	Water compatible	River flooding Flood Zone 3 Surface water 200 years - shallow Groundwater very high	Colne Valley viaduct will be in the floodplain between the River Colne and this receptor.
Broadwater Farm substation	Essential infrastructure	Groundwater very high	There will be no significant below ground construction within shared risk area. No shared pathway.
Broadwater Farm	Less vulnerable	Surface water 30 years - deep Groundwater very high	No shared pathway.

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Denham Aerodrome	Less vulnerable	Groundwater moderate	Flooding arises from superficial deposits, not connected with areas of risk that will be intercepted by the Proposed Scheme. No shared pathway.
Technical Exponents and Fairthorpe	Less vulnerable	Groundwater moderate	Flooding arises from superficial deposits, not connected with areas of risk that will be intercepted by the Proposed Scheme. No shared pathway.
Roughwood and The Bungalow	More vulnerable	Groundwater moderate	Flooding arises from superficial deposits, not connected with areas of risk that will be intercepted by the Proposed Scheme. No shared pathway.
Denham Water Ski Club	Water compatible	River flooding Flood Zone 3 Surface water 200 years - shallow Groundwater very high	Colne Valley viaduct will be at this location.
Weybeards Cottages substation	Essential Infrastructure	Surface water 200 years - shallow Groundwater very high	Colne Valley viaduct will be at this location.
Denham aerodrome north commercial area	Less vulnerable	Groundwater moderate	Flooding arises from superficial deposits, not connected with areas of risk that will be intercepted by the Proposed Scheme. No shared pathway.
Denham Manor nursing home	More vulnerable	Groundwater moderate	Flooding arises from superficial deposits, not connected with areas of risk that will be intercepted by the Proposed Scheme. No shared pathway.
Weybeards Cottages pumping station	Water Compatible	River flooding Flood Zone 2 Groundwater very high	Colne Valley viaduct will be approx. 700m downstream.
Denham Park Farm and March Cottage	More vulnerable	Surface water 30 years - deep	No shared pathway.

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Marish Farm residential area	Highly vulnerable	Groundwater moderate	Flooding arises from superficial deposits, not connected with areas of risk that will be intercepted by the Proposed Scheme. No shared pathway.
Oakwood House and Middle Halings	More vulnerable	Groundwater moderate	Flooding arises from superficial deposits, not connected with areas of risk that will be intercepted by the Proposed Scheme. No shared pathway.
Broadwater Sailing Club	Water compatible	River flooding Flood Zone 3 Groundwater very high Hilfield Park reservoir	Colne Valley viaduct will be approximately 1,200m downstream.
Weybeards Cottages	More vulnerable	River flooding Flood Zone 2 Surface water 200 years - shallow Groundwater very high	Colne Valley viaduct will be in the floodplain at this location.
Black Jacks Lock residential dwellings	More vulnerable	Groundwater very high Hilfield Park reservoir	No shared pathway.
Troy House and West Hyde House	More vulnerable	River flooding Flood Zone 2 Surface water 30 years - shallow Groundwater very high Hilfield Park reservoir	Colne Valley viaduct will be approximately 1,200m downstream.
Batchworth Dragon Boat Club and Rickmansworth Sailing Club	Water compatible	River flooding Flood Zone 3 Surface water 200 years - shallow Groundwater very high Hilfield Park reservoir	Colne Valley viaduct will be approximately 1,800m downstream.
Jacks Lane	More vulnerable	Surface water 30 years - deep Groundwater very high Hilfield Park reservoir	No shared pathway.
Troy Wharf industrial area	Less vulnerable	River flooding Flood Zone 3 Groundwater very high Hilfield Park reservoir	Colne Valley viaduct will be approximately 1,400m downstream.

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Colne Cottage	More vulnerable	River flooding Flood Zone 2 Groundwater very high	Colne Valley viaduct will be approximately 1,400m downstream.
Clancy Docwra	Less vulnerable	River flooding Flood Zone 3 Groundwater very high	Colne Valley viaduct will be approximately 2,000m downstream.
West Hyde village	More vulnerable	River flooding Flood Zone 2 Surface water 30 years - deep Groundwater very high Hilfield Park reservoir	Colne Valley viaduct will be approximately 2,000m downstream (river flooding). Chiltern tunnel south approach embankment will be approximately 500m upstream (surface water).
Coppermill pumping station and substation	Essential infrastructure	River flooding Flood Zone 2 Surface water 200 years - shallow Groundwater very high Hilfield Park reservoir	Colne Valley viaduct will be approximately 2,300m downstream.
Sunnyhill Road	More vulnerable	Groundwater moderate	No shared pathway.
Maple Cross village	More vulnerable	Surface water 30 years - deep Groundwater very high	No shared pathway.

8.1.2 There is also the potential for the Proposed Scheme to change the baseline risk of flooding described in Section 6 of this report. Though designed such that the probability of the Proposed Scheme flooding in any given year is less than 1 in 1,000, any change to the baseline risk of flooding could impact on the assessment of flood risk to the Proposed Scheme. All cases of flood risk discussed in Section 6 of this report are therefore reconsidered regardless of the presence or otherwise of third party local receptors.

8.2 Impact on risk of flooding from rivers

Newyears Green Bourne

Description

8.2.1 The Newyears Green Bourne (SWC-CFA7-02) is a tributary of the River Colne which it joins near Denham Lock approximately 2km downstream of the Proposed Scheme crossing. The Newyears Green Bourne floodplain is separated from the River Colne floodplain along this distance by the GUC which is slightly raised above surrounding ground. The Proposed Scheme will cross on viaduct the Newyears Green Bourne floodplain and Harefield No.2 Lake. Design elements that have the potential to affect

the risk of flooding from the Newyears Green Bourne are the Harvil Road diversion (part of the design within CFA6) and the Colne Valley viaduct.

8.2.2 The Proposed Scheme will cross the Newyears Green Bourne, the floodplain and Harefield No.2 Lake on viaduct. The Colne Valley south embankment (viaduct abutment) extends into the floodplain to the south. The viaduct crossing of the watercourse and floodplain will be skewed by approximately 60°. At the Newyears Green Bourne crossing, mitigation will include the addition of two meandering bends (approximately 10m either side from the current channel) over a distance of approximately 140m.

Local receptors and land use

8.2.3 Formal receptors within the 1km buffer extent that could be affected by the Proposed Scheme near the Newyears Green Bourne are Dews Farm and part of the HOAC.

8.2.4 The land use within the floodplain in the vicinity of the Proposed Scheme is largely made up of arable farm land and pasture, with the exception of the residential dwellings at Dews Farm and The Alders and leisure uses associated with the HOAC.

Assessment of effects

8.2.5 The proposed viaduct will be supported on single piers with a 4m square plan section located at 40m centres with the exception of the initial span which will be 30m. Since viaduct piers are proposed within the floodplain flow area of the Newyears Green Bourne the Proposed Scheme will potentially obstruct floodplain flows which could lead to increased water levels upstream of the Proposed Scheme.

8.2.6 The effect of the Proposed Scheme will vary between the valley crossing and the lake crossing, due to the differing hydraulic characteristics of each floodplain area. Flood waters at the valley crossing will be primarily flowing within the floodplain approximately parallel to the river channel, and hence the viaduct piers will potentially obstruct flood flows. Within the lake, which does not form a functional flow path north of the HOAC, flooding would manifest as a rise and fall in water levels, with less horizontal flow.

8.2.7 The proposed valley crossing will occur approximately 300m upstream of the outfall of the Newyears Green Bourne to Harefield No. 2 Lake. The Newyears Green Bourne was not included in the model of the River Colne provided by the Environment Agency.

8.2.8 Flood water levels in Harefield No. 2 Lake can be reasonably assumed to be similar to or less than levels in Savay Lake on the basis that normal levels would equalise due to the hydraulic conductivity in the underlying geology. Flow volumes in the Newyears Green Bourne would be small relative to the River Colne and when combined with the capacity of the lake, which has a plan area of over 175,000m^2, would be unlikely to significantly increase water levels. Consequently, flood water levels for Harefield No. 2 Lake have been taken from the Savay Lake reservoir node in the Environment Agency model.

8.2.9 The baseline estimates of maximum flood water levels at the crossing are presented in Table 8. The minimum top of rail level will be 47.7m AOD and the viaduct deck (rail to soffit) will be 4m deep, resulting in a minimum soffit level of 43.7m AOD. The viaduct

deck will clear the floodplain, with a freeboard between the 1 in 1,000 years return period (0.1% annual probability) flood water level and the minimum soffit of just less than 6m.

8.2.10 A conceptual model of the Newyears Green Bourne has been developed to include the viaduct in order to quantify the effect (afflux). Due to the viaduct skew the potential effect of the viaduct extends some distance upstream of the channel crossing. Results were extracted for the three design return periods at the channel crossing and are presented in Table 8.

Table 8: Estimated flood water levels in the Newyears Green Bourne at the channel crossing

	1% annual probability	**1% annual probability including climate change allowance**	**0.1% annual probability**
Baseline	37.08m AOD	37.10m AOD	37.27m AOD
Future	37.08m AOD	37.11m AOD	37.27m AOD
Maximum afflux	1mm	2mm	1mm
Maximum influence	Immediately upstream of viaduct		

8.2.11 The model shows that the viaduct will create a negligible afflux at the channel crossing location, with increases in modelled flood levels of up to 2mm calculated immediately upstream of the structure. Approximately 220m upstream of the viaduct where the Colne Valley south embankment extends into the floodplain, a more significant impact on flood levels is observed due to a reduction in the conveyance capacity of the floodplain as shown in Table 9. The effect of the Proposed Scheme extends to immediately downstream of Harvil Road.

Table 9: Estimated flood water levels in the Newyears Green Bourne at the maximum afflux location

	1% annual probability	**1% annual probability including climate change allowance**	**0.1% annual probability**
Baseline	37.81m AOD	37.84m AOD	37.94m AOD
Future	37.87m AOD	37.92m AOD	38.03m AOD
Maximum afflux	66mm	71mm	94mm
Maximum influence	Peak at 220m upstream of crossing, extending to Harvil Road, 320m upstream		

8.2.12 These increases in water level result in a moderate impact contained within the agricultural land between Harvil Road (moderate value receptor), the access road to the HOAC and the Proposed Scheme.

8.2.13 The built volume of the piers within the floodplain will displace flood water by removing floodplain storage. There will be seven piers located within the Newyears Green Bourne floodplain and 10 piers located within Harefield No. 2 Lake. The minimum ground levels at the crossing (normal water level within Harefield No. 2 Lake) are 37.1m AOD and 35.5m AOD respectively resulting in respective maximum flood water depths of 500mm and 1.7m. Each pier will have a 4m by 4m square plan

area, so maximum flood storage volumes of 56m^3 within the Newyears Green Bourne floodplain and 272m^3 within Harefield No. 2 Lake will be displaced as a result of the Proposed Scheme.

8.2.14 Replacement floodplain storage is proposed upstream of Harvil Road as part of a holistic mitigation strategy to include the effects of both the Colne Valley viaduct crossing and the Harvil Road diversion. This mitigation will be designed to ensure that there is no significant effect on the risk of flooding from the Newyears Green Bourne as a result of the Proposed Scheme.

River Colne

Description

8.2.15 The Proposed Scheme will cross the Colne Valley to the south and west of Harefield. The valley base is dominated by large gravel pit lakes, with the residential settlements of Harefield and Denham at the eastern and western extents of the valley respectively.

8.2.16 The Proposed Scheme will cross the full width of the valley on the Colne Valley viaduct (3.4km). The viaduct swings northwards whilst crossing the valley and will cross the valley at a gradually increasing skew relative to the flow direction (approximately 35° increasing to approximately 60°). At the crossing of the River Colne channel (SWC-CFA7-03), near the far north-western extent of the valley crossing, the viaduct will be approximately parallel to the channel direction.

8.2.17 A viaduct pier will be located within the River Colne channel. In order to prevent obstructing channel flows within the watercourse the channel will be realigned. The realignment will result in a narrowing of the channel and sharp meanders beneath the viaduct, which may increase frequency, extent and depth of flooding.

8.2.18 Although construction activities are not generally covered in this FRA due to their temporary nature, construction of the Colne Valley viaduct will be over an extended period (approximately five years) and the construction will impact on the risk of flooding and is therefore assessed in addition to permanent effects.

Local receptors and land use

8.2.19 There are a number of formal receptors within the 1km buffer extent that could be affected by the Proposed Scheme across the Colne Valley, as follows:

- Savay Lane residential area and Savay Farm are located within Flood Zone 2, on the western extent of the floodplain, downstream of the Proposed Scheme;
- around Moorhall Road, the Blackford Pumping Station, Horse and Barge Public House and Widewater Lock area residential dwellings fall within Flood Zone 2, predominantly upstream of the Proposed Scheme;
- Harleyford Aggregates gravel works and Broadwater Sailing Club are located within Flood Zone 3 on the banks of Broadwater Lake, upstream of the Proposed Scheme; and
- Denham Water Ski Club, Weybeards Cottages and the Weybeards Cottages pumping station and electricity substation are areas located partially within

Flood Zone 2 at the western extent of the floodplain, upstream of the Proposed Scheme.

8.2.20 The land use within the floodplain adjacent to the Proposed Scheme is the Colne Valley Regional Park mostly used for recreation and nature conservation purposes.

Assessment of effects

8.2.21 The dynamics of flooding in the area are heavily influenced by the presence of the gravel pit lakes. The detailed hydraulic modelling undertaken by the Environment Agency represents the floodplain as a series of separate lakes connected to both the Colne channel and each other by a series of spills. The model shows that in the 1 in 100 years return period (1% annual probability) flood event there is no interaction directly between the lakes with only small amounts of overtopping occurring during the 1 in 1,000 years return period (0.1% annual probability) flood event. Therefore, the main mechanism for flood water conveyance through the valley is via the channel of the watercourse itself and the potential for any significant impacts of the Proposed Scheme on the dynamic flooding processes will be limited to effects within the channel itself.

8.2.22 The Environment Agency hydraulic model suggests that dynamic floodplain flow away from the River Colne channel is negligible. As a result, there will be no significant effect on the dynamic characteristics of floodplain flow arising from piers or the temporary jetty (during the construction phase a jetty will be constructed across Harefield No. 2 Lake, a short section of Savay Lake, Kroda Lake and Long Lake) within the lakes or flood zones of the River Colne. Application of an afflux model, as has been applied at other locations within the Proposed Scheme, is therefore not necessary in this case.

8.2.23 There will, however, be temporary and permanent alterations to the dynamic characteristics within and adjacent to the River Colne resulting from the viaduct crossing and channel realignment.

8.2.24 A temporary jetty will be constructed across the River Colne and floodplain for construction of the viaduct. These works will result in obstruction of flood flows and loss of floodplain storage. In the vicinity of these works, the 1 in 100 years return period (1% annual probability) flood water level including an allowance for climate change varies between 37.73m AOD and 37.49m AOD. The top of bank and adjacent towpath is at approximately 37m AOD along this reach of the watercourse, which equates to a flood depth of approximately 500mm – 750mm above the towpath level.

8.2.25 The jetty will have a moderate impact on high and moderate value receptors with a resulting moderate and significant adverse effect.

8.2.26 The deck and supporting structure of the jetty will be designed to take account of the potential for increased flood risk through measures to be incorporated within a site-specific flood risk management plan. There remains the potential for the jetty to obstruct some flood flows temporarily during the construction works resulting in moderate impacts on flood risk to very high value receptors with a resulting large and significant adverse effect.

8.2.27 Land has been identified within the construction boundary of the Proposed Scheme upstream and downstream of the realignment. Where necessary, this will provide space to widen the River Colne or provide additional flow area at higher water levels. Mitigation measures which will be considered are described in Section 7.1.6.

8.2.28 There will be no permanent adverse effect on the risk of flooding from the River Colne due to the Proposed Scheme.

8.2.29 Regardless of the impact of the viaduct piers on the dynamic characteristics of the floodplain, the built volume of the piers within the floodplain will cause displacement of flood water through the removal of floodplain storage. There will be 37 piers located within the floodplain of the River Colne, each with a footprint area of 16m^2 above the pile cap. Of these piers:

- thirteen will be located within the Savay Lake area where water depths are up to 1.7m resulting in a total volume of displaced floodwater of approximately 353m^3;
- seventeen will be located within the Korda Lake and Broadwater Lake area, where water depths are up to 1.9m, resulting in a total volume of displaced floodwater of approximately 505m^3; and
- seven will be located around the channel area, with water depths of up to 1.5m resulting in a total volume of displaced floodwater of approximately 168m^3.

8.2.30 The combined potential maximum displaced volume will therefore be 1,026m^3. Replacement floodplain storage will be provided in two locations at the edge of the floodplain of the River Colne as shown on Map CT-06-019 and CT-06-020 (Volume 2, CFA7 Map Book).

Savay Lane residential area and Savay Farm

8.2.31 These receptors are located close to the western bank of the River Colne. According to the Environment Agency hydraulic model, at this location the water level in the channel is greater than the water level in Savay Lake. Therefore jetties and piers within Savay Lake, although potentially causing local displacement, are unlikely to have an effect on flood water levels within the western floodplain. There will therefore be no significant effect on the risk of flooding to these receptors.

Moorhall Road area

8.2.32 The Colne Valley viaduct will lie between these receptors and the River Colne. The risk of flooding would be dictated by levels in Savay Lake and Korda Lake. The replacement floodplain storage area will be designed to prevent any increase in flood water levels in the lakes and there will consequently be no significant permanent effect on the risk of flooding to these receptors. The proposed temporary jetty will potentially have a significant effect on the risk of flooding to these receptors.

Broadwater Lake

8.2.33 Harleyford Aggregates and Broadwater Sailing Club are located on the banks of Broadwater Lake. The replacement floodplain storage area will prevent any increase in flood water levels in the lakes and there will consequently be no significant effect on

the risk of flooding to these receptors. These receptors are located at the north and east of Broadwater Lake, and are the temporary jetty is not expected to have any significant effect on the risk of flooding to these receptors.

Denham Water Ski Club and Weybeards Cottages pumping station

8.2.34 The Denham Water Ski Club and Weybeards Cottages pumping station are located at the edge of Flood Zone 2 upstream of the Proposed Scheme and to the western side of the River Colne channel. The replacement floodplain storage area will prevent any increase in flood water levels in the lakes and there will consequently be no significant permanent effect on the risk of flooding to these receptors. The proposed temporary jetty will potentially affect water levels at this location. The clubhouse is located some distance from the edge of Flood Zone 2 and it is unlikely that flood water levels will rise sufficiently to create a risk of flooding to the building. There is potentially a significant effect on the risk of flooding at the Weybeards Cottages pumping station.

Lower Lodge dry valley

Description

8.2.35 The Ickenham National Grid feeder station will be located directly within an area shown on the Environment Agency flood zone mapping to be at risk of flooding arising from upstream reaches of the Newyears Green Bourne. The footprint of the National Grid feeder station occupies approximately 50% of the width of Flood Zone 3, and will displace floodwaters.

Local receptors and land use

8.2.36 There are no formal receptors within the area at risk from this source in the study area, with the exception of Lower Lodge upstream of the Proposed Scheme. The area of risk encompasses agricultural land belonging to Park Lodge Farm and will cross a public footpath downstream of the Ickenham National Grid feeder station.

Assessment of effects

8.2.37 The LiDAR data for the area surrounding the National Grid feeder station shows that ground levels slope away from the National Grid feeder station relatively steeply down towards Harefield No. 2 Lake. Any effect on floodplain storage will be limited by the slope of the ground in the area, although it is possible that some effect due to obstruction of flows and displacement of floodplain storage may still be observed. Replacement floodplain storage will be provided to ensure that the feeder station does not result in a significant effect on the agricultural land.

8.3 Impact on risk of flooding from surface water

Colne Valley viaduct

8.3.1 The FMfSW shows scattered areas of the River Colne floodplain to be at risk of shallow (between 100mm and 300mm in depth) or deep (greater than 300mm in depth) flooding from direct runoff during both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events. Since the Proposed Scheme will be on viaduct across the floodplain, there will be no continuous barrier to overland flow. Surface water runoff will divert around viaduct piers if they fall within

overland flow paths, and due to the scattered nature of the risk areas, this will not result in any significant changes in the risk of flooding to third party receptors. There will be no viaduct piers located within areas that appear to be at risk due to ponded surface water flows, and consequently there will be no loss in flood storage volume.

8.3.2 The extents of flooding shown are generally within the extents at risk of flooding from the River Colne and Newyears Green Bourne and, since flooding from direct runoff occurs early in any given rainfall event, is likely to have receded prior to the onset of any significant flooding from the watercourses. On this basis, there is unlikely to be any significant cumulative effect due to combined flooding from direct runoff and from the watercourse that would not already be accounted for in the hydraulic analysis of the rivers used to assess the baseline case and the likely effect arising from the Proposed Scheme.

8.3.3 There will be no significant effect on the risk of flooding from direct runoff in the vicinity of the Colne Valley viaduct. Consequently, potential effects on the risk of flooding to third party receptors will be negligible.

Old Shire Lane

8.3.4 Approximately 1km south-east of the M25, the Proposed Scheme will intersect with the confluence of several dry valleys arising from the hills to the west of the Proposed Scheme. Design elements within the area shown to be at risk are the Chiltern tunnel south approach embankment.

8.3.5 At the crossing location four separate valleys combine to follow a single flow path north-east across Tilehouse Lane to the River Colne. The total catchment size for the four valleys at the Proposed Scheme crossing is 6.9km^2, with resultant potential flood flow volumes in the 1 in 200 years return period of 0.9m^3/s. The Proposed Scheme will collect surface runoff into the land drainage system and discharge beneath the Proposed Scheme in a 1,350mm diameter culvert designed to convey the 1 in 100 years return period flood flow including allowances for climate change, blockage and siltation.

8.3.6 Balancing ponds are proposed upstream of the A412 North Orbital Road to avoid reducing downstream conveyance times and there will consequently be no impact on the risk of flooding from this source arising from the Proposed Scheme.

8.4 Impact on risk of flooding from groundwater

8.4.1 Assessments of all groundwater effects are detailed within the CFA7 water resources assessment (Volume 5: Appendix WR-002-007). The Proposed Scheme is not expected to have any significant long term impacts on groundwater levels within the bedrock or superficial aquifers within the study area. Although the Chiltern tunnel and portal will potentially pass through the principal bedrock aquifer, all construction is expected to be above the water table in this study area. Piling for the viaduct will penetrate the chalk aquifer within the Colne Valley, but the depth and area required however, are not considered significant in comparison with the extent and depth of the chalk aquifer. There will therefore be no significant effects on the risk of flooding from groundwater as a result of the Proposed Scheme.

8.5 Impact on risk of flooding from drainage systems

8.5.1 The Proposed Scheme will not pass through any urban areas for the full extent within CFA7. All highway crossings required will be diverted or re-designed as bridges or underpasses, with the exception of those that will be crossed on viaduct, which will remain unchanged. Highway drainage for all new or realigned roads will be designed in accordance with the relevant design guides and regulations, and consequently no increase in the risk of flooding arising from overloaded highway drains is anticipated.

8.6 Impact on risk of flooding from artificial sources

Grand Union Canal

8.6.1 The risk of flooding due to a breach or overtopping of the GUC embankments is extremely low for a number of structural and hydraulic reasons as detailed in Section 6. The only factor which could potentially be influenced by the Proposed Scheme, which will be raised on viaduct at the crossing of the GUC, is the structural integrity of the canal embankment.

8.6.2 Piers will be constructed immediately adjacent to the GUC on both sides. Detailed method statements will be prepared for construction to avoid compromising the canal embankment. Consequently, the Proposed Scheme will not have a significant impact on the risk of flooding from the GUC.

Harefield No.3 Reservoir

8.6.3 Where the Colne Valley viaduct will cross the area with a residual risk of impounded reservoir failure at Harefield No.3, it will be raised above the floodplain for the crossing of the Colne Valley. The modelled extent of the residual risk of reservoir failure is shown to be within the extent of the area at risk of flooding from the Newyears Green Bourne. The length of the viaduct has been designed to span the floodplain of the Newyears Green Bourne, so no embankments will be constructed within the reservoir flood risk area. It is expected that flooding in the vicinity of the Proposed Scheme would take the form of slightly elevated flood flows and levels within Harefield No.2 Lake.

8.6.4 The Ickenham National Grid feeder station will lie within the area with a residual risk of impounded reservoir failure and will create a potential obstruction to flood flows. Any overland flooding arising from failure of the Harefield No.3 reservoir will be diverted around the National Grid feeder station. Obstruction to flood flows arising from built volume within the area at risk will potentially increase the risk of flooding immediately adjacent to the Proposed Scheme.

8.6.5 Although there is a potential impact on the residual risk of flooding from the reservoir, since this water body is subject to the requirements of the Reservoirs Act the likelihood of such flooding occurring is extremely low. Further, mitigation measures employed against the potential impact of flooding from the Newyears Green Bourne will apply to the risk of flooding from the Harefield No.3 Reservoir. Replacement floodplain storage will be provided for the loss in flood capacity for river flooding which will also be effective in the event of overland flow resulting from failure of the

reservoir. The impact of the Proposed Scheme on the actual risk of flooding from impounded reservoir failure will be negligible.

Hilfield Park Reservoir

8.6.6 Where the Proposed Scheme will cross the area with a residual risk of impounded reservoir failure, it will be on viaduct for the crossing of the Colne Valley. The modelled extent of the residual risk of reservoir failure is shown to be within the extent of the area at risk of flooding from the River Colne. The length of the viaduct has been designed to span the floodplain and therefore no embankments will be constructed within the reservoir flood risk area. The reservoir is located approximately 20km upstream of the Proposed Scheme, near Borehamwood, and the Proposed Scheme will cross the area of risk at the far downstream extent. At the crossing location, the extent of the area at risk is confined to the river channel. Consequently, it is expected that flooding in the vicinity of the Proposed Scheme would take the form of slightly elevated flood flows and levels within the River Colne.

8.6.7 Although there is a potential impact on the residual risk of flooding from the reservoir, since this water body is subject to the requirements of the Reservoirs Act the likelihood of such flooding occurring is extremely low. Further, mitigation measures employed against the potential impact on flooding from the River Colne will apply to the risk of flooding from the Hilfield Park Reservoir. The impact of the Proposed Scheme on the actual risk of flooding from impounded reservoir failure will be negligible.

8.7 Summary of potential impacts and effects on flood risk

Table 10: Summary of potential flood risk impacts and effects in CFA7

Receptor	Vulnerability classification	Pathway	Impacts and effects
General Proposed Scheme	N/A	River	Potentially significant afflux and loss of floodplain storage at Colne Valley viaduct crossing of Newyears Green Bourne, to be offset by mitigation in the form of replacement floodplain storage. Potential loss of floodplain storage due to the Ickenham National Grid feeder station, to be offset by replacement floodplain storage. Significant effect from the temporary jetty constructed across the River Colne.
		Surface water	No significant effects expected.
		Groundwater	No significant effects expected.
		Drainage systems	No significant effects expected.
		Artificial sources	No significant effects expected.
HOAC	Less vulnerable	Groundwater high Harefield No.3 Reservoir	No significant effects expected.

Receptor	Vulnerability classification	Pathway	Impacts and effects
Lower Lodge	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - shallow Harefield No.3 Reservoir	Receptor sufficiently upstream of Proposed Scheme. No significant effects expected.
Savay Lane residential dwellings	More vulnerable	River flooding Flood Zone 2 Surface water 30 years - deep Groundwater very high	No significant effects expected.
Savay Farm	More vulnerable	River flooding Flood Zone 2 Groundwater very high	No significant effects expected.
Blackford pumping station and substation	Essential infrastructure	River flooding Flood Zone 2 Groundwater very high	Potential significant effect from the temporary jetty constructed across the River Colne.
Horse and Barge public house	More vulnerable	River flooding Flood Zone 2 Groundwater very high	Potential significant effect from the temporary jetty constructed across the River Colne.
Widewater Lock residential dwellings	More vulnerable	River flooding Flood Zone 2 Groundwater very high	Potential significant effect from the temporary jetty constructed across the River Colne.
Harleyford Aggregates	Water compatible	River flooding Flood Zone 3 Surface water 200 years - shallow Groundwater very high	No significant effects expected.
Denham Water Ski Club	Water compatible	River flooding Flood Zone 3 Surface water 200 years - shallow Groundwater very high	No significant effects expected.

Receptor	Vulnerability classification	Pathway	Impacts and effects
Weybeards Cottages substation	Essential infrastructure	Surface water 200 years - shallow Groundwater very high	Potential significant effect from the temporary jetty constructed across the River Colne.
Weybeards cottages pumping station	Water compatible	River flooding Flood Zone 2 Groundwater very high	No significant effects expected.
Broadwater Sailing Club	Water compatible	River flooding Flood Zone 3 Groundwater very high Hilfield Park reservoir	No significant effects expected.
Weybeards Cottages	More vulnerable	River flooding Flood Zone 2 Surface water 200 years - shallow Groundwater very high	No significant effects expected.
Troy House and West Hyde House	More vulnerable	River flooding Flood Zone 2 Surface water 30 years - shallow Groundwater very high Hilfield Park reservoir	No significant effects expected.
Batchworth Dragon Boat Club and Rickmansworth Sailing Club	Water compatible	River flooding Flood Zone 3 Surface water 200 years - shallow Groundwater very high Hilfield Park reservoir	No significant effects expected.
Troy Wharf industrial area	Less vulnerable	River flooding Flood Zone 3 Groundwater very high Hilfield Park reservoir	No significant effects expected.

Receptor	Vulnerability classification	Pathway	Impacts and effects
Colne Cottage	More vulnerable	River flooding Flood Zone 2 Groundwater very high	No significant effects expected.
Clancy Docwra	Less vulnerable	River flooding Flood Zone 3 Groundwater very high	No significant effects expected.
West Hyde village	More vulnerable	River flooding Flood Zone 2 Surface water 30 years - deep Groundwater very high Hilfield Park reservoir	Collection and attenuation of surface water flows will result in no increase in the risk of flooding downstream. No significant effects expected.
Coppermill pumping station and substation	Essential infrastructure	River flooding Flood Zone 2 Surface water 200 years - shallow Groundwater very high Hilfield Park reservoir	No significant effects expected.

9 Conclusions

9.1 Summary

9.1.1 The Proposed Scheme within CFA7 extends from Harvil Road in LBHi to the M25 north of Denham. The study area includes all areas within 1km of the Proposed Scheme which includes areas at risk of flooding from all sources as follows:

- areas at risk of river flooding from the River Colne and Newyears Green Bourne;
- areas at risk of flooding arising from surface water;
- areas susceptible to groundwater emergence and thus at risk of groundwater flooding; and
- areas at risk of inundation should the Harefield No.3 or Hilfield Park reservoirs fail.

9.1.2 The Proposed Scheme will be at least 1m above design flood water levels within all areas at risk of flooding from rivers, surface water, groundwater, drainage and artificial water body sources. Residual risks from these sources will be negligible. Design standards are such that no flooding of the Proposed Scheme will be expected in the design flood events under normal operating conditions.

9.1.3 The Ickenham National Grid feeder station will be located within Flood Zone 3 and an area at risk of flooding in the event of failure of the Harefield No.3 Reservoir. Mitigation will be required to make the feeder station resilient against flooding.

9.1.4 The dominant land use in CFA7 is rural agriculture apart from the Colne Valley Regional Park. In order to prevent general impacts on flood risk and river morphology resulting from the Proposed Scheme, the following mitigation will be included:

- provision of replacement floodplain storage to prevent displacement of floodwaters within areas at risk of flooding from rivers;
- provision of storage and surface water balancing ponds to maintain peak flows and volumes collected within the Proposed Scheme within existing discharge parameters;
- design of culverts with internal headroom and allowances for siltation to minimise the chances of blockage or future capacity restrictions; and
- inclusion of a 30% allowance for climate change on all design rainfall events and 20% on all river flows.

9.1.5 During construction works flood conveyance capacity will be reduced by the presence of a temporary jetty across the River Colne resulting in a moderate impact on very high value receptors and a large and significant effect. Until design of the temporary jetty is complete and the site specific flood risk management plan is agreed with the Environment Agency, a potentially significant temporary effect on the risk of flooding from the River Colne remains.

9.1.6 There will be no permanent significant effects arising from the Colne Valley viaduct in relation to the risk of flooding from the River Colne or Newyears Green Bourne, as a result of the following design measures:

- replacement floodplain storage will be provided upstream of Harvil Road as part of a holistic mitigation solution to offset impacts arising from the Colne Valley viaduct and the Harvil Road diversion;
- the realignment of the Newyears Green Bourne channel will be designed to maintain conveyance and capacity;
- the permanent River Colne channel realignment will include channel improvements to maintain conveyance and capacity within the watercourse and no increase in the frequency of overtopping to the lakes either upstream or downstream of the watercourse realignment; and
- replacement for losses in floodplain storage will be provided, with two areas of land included within the extent of the Proposed Scheme at the edge of the River Colne floodplain.

9.1.7 Replacement floodplain storage will be provided at the Ickenham National Grid feeder station to offset any losses in floodplain storage.

9.2 Residual flood risks to Proposed Scheme

9.2.1 Residual flood risks arise in situations that are not included in standard design scenarios, for example when a culvert becomes blocked causing flooding upstream. All design is generally undertaken assuming that existing infrastructure is functioning under normal conditions. Consequently, there may be areas where the potential severity of flooding may exceed the design standard under certain circumstances.

Residual flood risks from rivers

9.2.2 There are no locations within CFA7 where the failure or blockage of a hydraulic structure would lead to an increase in the severity of flooding sufficient to create a residual risk of flooding to the Proposed Scheme. Flood waters would need to rise by more than 10m across the full width of the Colne Valley Regional Park to pose a risk of flooding to the Colne Valley viaduct.

Residual flood risks from surface water and minor watercourses

9.2.3 All culverts within the Proposed Scheme are designed with a minimum internal headroom of 600mm above the design flood water level to minimise the risk of blockage. There is therefore not expected to be any significant increased risk of flooding at minor watercourses and dry valley crossings arising from potential blockage of culverts.

9.2.4 There are no minor watercourse crossings within CFA7 where significant hydraulic structures exist within a reasonable hydraulic distance either upstream or downstream which could create significant additional risks of flooding to the Proposed Scheme due to blockage or failure.

Residual flood risks from groundwater

9.2.5 Groundwater levels rise and fall relatively slowly and for any change to occur in the risk of flooding from this source below ground intervention is required. The risk of flooding from groundwater already considered therefore presents an absolute risk, and there are no significant residual risks arising from this source.

Residual flood risks from drainage systems

9.2.6 There are no areas within CFA7 where a significant risk of flooding exists from drainage systems or artificial sources. Consequently, there are no expected residual risks from these sources.

Residual flood risks from artificial and surface water bodies

9.2.7 Within CFA7 the only area of flood risk associated with an artificial or surface water body is the inundation area associated with failure of the Harefield No.3 or Hilfield Park Reservoirs. The Environment Agency methodology considers the consequences of total failure of the reservoir and therefore no further residual risks arise.

9.3 Residual effects of the Proposed Scheme on flood risk

9.3.1 Following mitigation for impacts on the risk of flooding arising from the Proposed Scheme, there will be slight residual effects on the risk of flooding due to changes to geometry, floodplain flow characteristics and river morphology at the River Colne and Newyears Green Bourne. Such effects are limited to the reshaping of floodplain extents arising from replacement floodplain storage and watercourse realignments with no significant residual effects on third party receptors.

9.3.2 All culverts within the Proposed Scheme are designed to convey the 1 in 100 years return period (1% annual probability) flow including an allowance for climate change with a minimum internal headroom of 600mm above the design flood water level to minimise the risk of blockage. Consequently, there will be a negligible increase in upstream residual flood risks arising from the introduction of culverts within the Proposed Scheme.

9.4 Compliance with local planning policy

9.4.1 The Proposed Scheme includes an allowance for future increases in the risk of flooding as a result of climate change by adding a 20% increase to design river flows and a 30% increase to rainfall intensities and flows in minor watercourses as recommended in the NPPF Technical Guidance document. SuDS in the form of balancing ponds and the creation of open channel land drainage are used wherever feasible in this CFA.

9.4.2 Although not in direct contravention of the Thames Region CFMP, the introduction of additional culverts is at variance with the general aims of the CFMP which seeks to restore culverted watercourses and enhance natural floodplains. In addition, the LBHi SFRA stipulates that "development should provide compensatory storage on a level-for-level basis to ensure there is no loss in flood storage capacity". As part of the Proposed Scheme, where losses in natural storage capacity are identified, mitigation will be provided in the form of replacement floodplain storage. Although minimised

wherever possible, there is no practical way to avoid culverting and floodplain crossings, due to the linear nature of the Proposed Scheme. The Newyears Green Bourne and the River Colne will be crossed on a clear-span structure with access alongside the watercourse maintained.

9.4.3 The Proposed Scheme is consistent with the requirements of the LBHi, SBDC and TRDC core strategies.

10 References

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